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RESEARCH MEMORANDUM

EFFECTS OF TWO TRAILING-EDGE CONTROLS ON THE AERO-
DYNAMIC CHARACTERISTICS OF A RECTANGULAR WING
AND BODY COMBINATION AT MACH NUMBERS FROM
3.00 TO 5.05

By Hermilo R. Gloria and Thomas J. Wong

Ames Aeronautical Laboratory
Moffett Field, Calif.

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EFFECTS OF TWO TRAILING-EDGE CONTROLS ON THE AERO-
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3.00 TO 5.05

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SUMMARY

An investigation was made to determine experimentally the effects of two types of trailing-edge controls on the aerodynamic characteristics of a wing-body combination consisting of a 4-percent-thick wing of rectangular plan form and a slender body of revolution. The two controls were a full-span, 20-percent-chord, plain (unbalanced) flap and a full-span trailing-edge spoiler. Tests were conducted at Mach numbers of 3.00, 4.23, and 5.05, angles of attack up to 12° , and control deflections up to $\pm 30^\circ$ for the flap and ± 8 -percent chord for the spoiler.

The variations of lift coefficient with angle of attack of the flap-wing-body combination and spoiler-wing-body combination were generally nonlinear. At angles of attack greater than 4° , losses in lift effectiveness and control effectiveness were observed for most of the negative control deflections. Flap control loads and flap hinge moments were adequately predicted at zero angle of attack by a shock-expansion method for two-dimensional flow. The predicted control loads combined with the predictions of linear theory for the wing (including interference effects) and experimental results for the body were found to give adequate estimates of lift and pitching moment of the flap-wing-body combinations.

Comparisons of the flap and spoiler controls for equal projected heights above or below the wing surface showed that the flap control was more effective in producing lift and pitching moment than the spoiler control for most of the projected heights tested. At a given value of lift coefficient, the flap control contributed less drag than the spoiler control.



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INTRODUCTION

Considerable research has been devoted recently to studies of conventional trailing-edge controls, such as flaps and spoilers, particularly at Mach numbers up to about 3. At higher supersonic speeds, however, comparatively few studies of these controls have been made. In addition, the capability of current supersonic-flow theories to predict the characteristics of flaps and spoilers has been studied for only a few cases (e.g., refs. 1 through 4). To provide additional information on flaps and spoilers at higher Mach numbers, tests have been conducted in the Ames 10- by 14-inch supersonic wind tunnel to study the effect of two such trailing-edge controls on the aerodynamic characteristics of a wing-body combination at Mach numbers from 3.00 to 5.05, angles of attack from -2° to $+12^\circ$, and Reynolds numbers ranging from 0.53 to 1.19 million (based on wing chord). The controls tested were a full-span, 20-percent-chord, plain (unbalanced) flap and a full-span trailing-edge spoiler. Results of this investigation are presented and compared with available theories.

SYMBOLS

A_b	body base area
A_f	flap plan area, exposed
c	wing chord
c_f	flap chord
C_D	drag coefficient, $\frac{\text{drag}}{qA_b}$
C_L	lift coefficient, $\frac{\text{lift}}{qA_b}$
C_m	pitching-moment coefficient (moment about body nose), $\frac{\text{pitching moment}}{qA_b l}$
C_N	normal-force coefficient, $\frac{\text{normal force}}{qA_b}$
C_h	hinge-moment coefficient, $\frac{\text{hinge moment}}{qA_f c_f}$
ΔC_L	incremental lift coefficient due to control deflection, $\frac{\text{incremental lift}}{qA_b}$

- ΔC_m incremental pitching-moment coefficient about body nose due to control deflection, $\frac{\text{incremental moment}}{qA_b l}$
- h spoiler height measured from airfoil surface, percent wing chord (positive for downward extension)
- l body length
- M free-stream Mach number
- q free-stream dynamic pressure
- r body radius
- r_b body radius at base
- x longitudinal coordinate
- α angle of attack of body
- δ control deflection angle measured from wing-chord plane (negative for upward deflection)
- δ' projected control height measured from airfoil surface and normal to wing-chord plane, percent chord

EXPERIMENT

Test Apparatus and Techniques

The tests were conducted in the Ames 10- by 14-inch supersonic wind tunnel at Mach numbers of 3.00, 4.23, and 5.05. A detailed description of this wind tunnel and its characteristics can be found in reference 5.

Lift, drag, and pitching moment of the complete model were measured by a three-component strain-gage balance. Forces parallel and perpendicular to the balance axis and moments about the model base were measured directly. All forces were then resolved to lift, drag, and pitching moment about the nose of the model. Hinge moments were measured by strain gages mounted within the model. Angles of attack greater than the $\pm 5^\circ$ range of the model-balance assembly were obtained by the use of bent sting supports. Air loads on these supports were essentially eliminated by shrouds that extended to within 0.040 inch of the model base.

Body base pressures were measured in all tests and the resultant base forces (referred to free-stream static pressure) were subtracted from the total forces so that the data presented are for forces ahead of the body base.

Stream static and dynamic pressures were determined from wind-tunnel calibrations and from tunnel stagnation pressures measured by a Bourdon type gage. Reynolds numbers (based on wing chord) for the tests were:

<u>Mach number</u>	<u>Reynolds number, million</u>
3.00	1.19
4.23	1.09
5.05	.53

Models

Principal dimensions of the wing-body combination and controls tested are shown in figure 1. The wing had a 4-percent-thick biconvex section, with a 50-percent-blunt trailing edge, and a rectangular plan form with an aspect ratio of 1 (for exposed panels joined together). The support body had an over-all fineness ratio of 12, consisting of a fineness-ratio-3 nose with a 3/4-power profile (see ref. 6), faired to a cylindrical afterbody of fineness ratio 9. The ratio of body radius to wing semispan was 0.40. Results of tests on the same configuration employing the wings as all-movable controls are presented in reference 7.

Two full-span trailing-edge controls were tested. One was a plain flap (unbalanced) with a chord length equivalent to 20-percent wing chord and the hinge line at the leading edge of the flap. The other was a spoiler consisting of a full-span projection at the trailing edge of the wing. Flap hinge moments were measured directly on a separate model, identical to the one described previously, by the use of an internally mounted strain-gage balance.

Accuracy of Results

Stream conditions.- Stream Mach number in the region of test models did not vary more than ± 0.02 from the mean values of 3.00, 4.23, and 5.05. Corresponding variations in stream static and dynamic pressures were sufficiently small so that buoyancy corrections were not necessary. Deviations in Reynolds number from the values previously given did not exceed $\pm 10,000$. The estimated error in angle-of-attack values did not exceed $\pm 0.2^\circ$.

The following table of uncertainties represents the maximum possible errors involved in the measurement of the aerodynamic forces and moments.

Component	M = 3.00	M = 4.23	M = 5.05
C_D	± 0.01	± 0.02	± 0.02
C_L	± 0.01	± 0.02	± 0.02
C_m	± 0.01	± 0.01	± 0.02
C_h	± 0.005	± 0.01	± 0.01

RESULTS AND DISCUSSION

Results of the experimental investigation of two trailing-edge controls are presented in figures 2 through 10. The data are also presented in table I in the form of lift, drag, normal-force, pitching-moment, and hinge-moment coefficients as a function of angle of attack.

Trailing-Edge Flap Control

Wing-body combination characteristics.— The variations of lift coefficient of the wing-body combination with angle of attack, drag coefficient, and pitching-moment coefficient are presented in figure 2 for all Mach numbers and control angles tested. In general, the results presented in figure 2 show no great change in aerodynamic characteristics as test Mach number is increased, other than the expected decrease in lift effectiveness with increasing Mach number. The variation of C_L with α is generally nonlinear, with $C_{L\alpha}$ increasing with increasing angle of attack.

The variations with flap deflection angle of lift and pitching-moment coefficients for the combination are presented in figure 3. In general, for angles of attack greater than 0° , the curves show some reduction in control effectiveness, $\partial C_m / \partial \delta$, as control deflections range from positive to negative control angles, that is, as the control projections go from the high-pressure side of the airfoil to the lee or low-pressure side. This is most evident at angles of attack of 8° and 12° , where there are no appreciable changes in C_L and C_m as δ changes from -20° to -30° . Although most of this loss in effectiveness

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can be accounted for from inviscid theoretical considerations, shock-induced separation of the laminar boundary layer ahead of the flap hinge line may also contribute further losses at the large negative control angles.

For purposes of comparison, theoretical estimates of C_L and C_m are also presented in figure 3. The theoretical estimates of C_L and C_m for the wing-body combination were obtained in the following manner: First, experimental values of C_L and C_m for the body alone were obtained from reference 8. The forces and moments due to the wing and to wing-body interference were calculated after the method of reference 9.¹ The incremental lift and pitching-moment coefficients due to control deflection, ΔC_L and ΔC_m , were estimated by use of the slender-airfoil shock-expansion method of reference 10.² The summation of these three contributions is presented in figure 3 as the theoretical estimates of C_L and C_m .

Comparison of the predictions of the theory with measured results (fig. 3) shows that the predictions of lift coefficient are in good agreement throughout the range of test parameters. Agreement between theoretical and measured values of pitching-moment coefficient is generally satisfactory for flap angles less than 20° .

Hinge-moment characteristics.— The variations with angle of attack of the flap hinge-moment coefficients, C_h , are presented in figure 4. In general, the variation of C_h with α is linear for small values of δ ($|\delta| \leq 10^\circ$). For large negative control angles, the values of C_h decrease sharply as α is increased above 0° . This change is thought to stem from flow separation ahead of the hinge line induced by shock-wave boundary-layer interaction. For large positive flap deflections, however, no abrupt change in C_h with increasing α is apparent. The variations of C_h with flap angle, presented in figure 5, are also nonlinear. The nonlinearity at large positive flap deflections, for the most part, is due to the nonlinear variation of pressure coefficient with flow deflection angles. For the large negative flap deflections, the nonlinearities are possibly due to the effects of shock-wave boundary-layer interaction.

Comparisons of experimental results with predictions of shock-expansion theory are made in figure 4. The theory gives adequate predictions of flap hinge-moment coefficient for flap deflections from -20° to $+30^\circ$ over the test range of angle of attack. For the largest

¹Reference 9 presents estimates of C_L and C_m for all-movable wing-body combinations. The values used in the present report are for values of the undeflected wing ($\delta = 0^\circ$).

²The method of reference 10 is applicable to two-dimensional flow only. Additional computations involving three-dimensional effects were not included since no improvement in the predicted values of C_L and C_m was obtained by using these additional computations.

negative flap deflection, however, the agreement between theoretical and experimental values of C_h is poor for angles of attack greater than 0° . This difference again is attributed to shock-wave boundary-layer interaction effects.

Trailing-Edge Spoiler Controls

Wing-body combination characteristics.- Variations of lift coefficient of the wing-body combination with angle of attack, drag coefficient, and pitching-moment coefficient are presented in figure 6 for all Mach numbers and spoiler heights tested. There is no large change in the aerodynamic characteristics of the combination with increasing Mach number other than the expected decrease in lift effectiveness. In general, the curves presented no marked dissimilarity from the results presented for the flap control.

Figure 7 shows the variation of measured lift and pitching-moment coefficients with spoiler heights at various angles of attack of the wing-body combination. Again the marked similarity between these results and those for the flap is evident. Both lift and moment coefficients show the same trend as with the flaps, that is, a decreasing control effectiveness for spoiler deflections ranging from positive to negative values for all angles of attack greater than 0° .

A comparison of the relative effectiveness of flap and spoiler controls is made in figures 8 and 9 for $M = 3.00$. The lift and pitching-moment coefficients of the control-wing-body combinations are presented as a function of the projected height of the controls above or below the airfoil surface and normal to the wing-chord plane. It can readily be seen that, for equal control heights, the flap control is usually more effective than the spoiler control throughout the range of control heights presented. The flap control gives increases in effectiveness ranging from about 10 percent at the large angles of attack to 100 percent at $\alpha = 0^\circ$ for most positive control heights. For most negative control heights at $\alpha \neq 0^\circ$, the advantage of the flap control is more pronounced since the spoiler tends to lose its lift and pitching-moment effectiveness altogether. An additional comparison is made in figure 10 where the relative efficiencies of the two control-wing-body combinations are presented. It is seen that, for equal control heights, the flap control contributes less drag than the spoiler control at a given value of lift coefficient of the test model. In addition, since the flap control has been shown to be a more effective control than the spoiler, it can be assumed that the projected control height of the spoiler will be larger than that of the flap control to produce trimmed conditions for the test configuration. This, in turn, would lead to an additional drag penalty associated with the use of spoiler controls.

CONCLUSIONS

An experimental investigation of the effects of two types of full-span trailing-edge controls on the aerodynamic characteristics of a wing-body combination has been made at Mach numbers of 3.00, 4.23, and 5.05, and Reynolds numbers ranging from 1.19 to 0.53 million. An analysis of the results for the 20-percent-chord plain flap control and the spoiler control, and comparison of experimental results with available theory have led to the following conclusions:

1. The variation of lift coefficient with angle of attack of the flap-wing-body combination is generally nonlinear, with the slope of the lift curves increasing with increasing angle of attack. Losses in control effectiveness are noted for large negative control angles at angles of attack greater than about 4° . In general, flap control effectiveness decreased with increasing Mach number.
2. The aerodynamic characteristics of the spoiler-wing-body combinations show the same trends as the flap-wing-body combination. Comparisons of the flap and spoiler controls for equal projected heights above or below the wing surface show that the flap control is more effective in producing lift and pitching moment than the spoiler control for most of the control heights tested. At a given value of lift coefficient, the flap control contributes less drag than the spoiler control.
3. The aerodynamic characteristics of the flap-wing-body combinations are predicted with reasonable accuracy by a method that combines theoretical values of wing and control loads with experimental results for the body alone. The theoretical wing loads (including interference effects) are calculated by linear-theory methods, and the control loads are calculated by a two-dimensional shock-expansion method.
4. Flap hinge moments vary linearly over the angle-of-attack range for flap deflections from -10° to $+10^\circ$. For large negative flap deflections the variation of hinge moments with angle of attack are nonlinear, due apparently to the effects of shock-wave boundary-layer interaction. For large positive flap deflections, hinge moments are nonlinear due to the nonlinear variation of pressure coefficient with flow deflection angle. The two-dimensional shock-expansion method gives adequate predictions of hinge-moment coefficients for flap deflections from -20° to $+30^\circ$ for the entire range of angles of attack. For -30° control deflection the predictions of the theory are poorer. In general, hinge-moment coefficients decreased with increasing Mach number.

Ames Aeronautical Laboratory
National Advisory Committee for Aeronautics
Moffett Field, California, Nov. 7, 1955

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TABLE I.- AERODYNAMIC CHARACTERISTICS OF CONTROL-WING-BODY COMBINATIONS
(a) Trailing-edge flap control

M = 3.00							M = 4.23							M = 5.05						
δ , deg	α , deg	C_L	C_D	C_m	C_h	C_N	δ , deg	C_L	C_D	C_m	C_h	C_N	δ , deg	C_L	C_D	C_m	C_h	C_N		
0	-2.1	-0.377	0.210	0.214	0.021	-0.384	-2.0	-0.313	0.155	0.165	0.025	-0.313	-2.0	-0.255	0.151	0.110	0.024	-0.260		
0	0	-0.37	.174	.019	0	-.037	0	-.034	.133	.015	.011	-.034	0	-.020	.134	-.006	.011	-.020		
1.0	1.0	.120	.199	-.071	-.010	.123	1.0	.103	.137	-.060	.004	.103	1.0	.109	.139	-.074	.005	.111		
2.1	2.1	.290	.109	-.172	-.021	.297	2.0	.244	.149	-.137	-.003	.244	2.0	.236	.153	-.144	.003	.241		
4.2	4.2	.667	.240	-.398	-.041	.683	2.9	.419	.171	-.253	-.032	.427	2.9	.414	.171	-.248	-.019	.422		
7.1	7.1	1.474	-	-.901	-.082	1.508	5.0	.728	.225	-.435	-.041	.744	4.9	.707	.223	-.404	-.030	.724		
10.2	10.2	2.269	.586	1.408	-.108	2.338	7.0	1.089	.299	-.645	-.054	1.117	6.9	1.017	.306	-.563	-.040	1.046		
12.3	12.3	2.655	.782	1.588	-.125	2.761	8.0	1.402	.346	-.823	-.064	1.436	7.9	1.197	.336	-.666	-.054	1.232		
							10.0	1.796	.471	-1.057	-.078	1.850	9.9	1.544	.447	-.863	-.064	1.598		
							12.1	2.212	.629	-1.314	-.091	2.295	12.0	1.913	.590	-1.068	-.075	1.993		
-10	-4.2	-.866	.291	.547	.132	-.885	-2.0	-.328	.167	.212	.069	-.334	-2.0	-.303	.169	.192	.048	-.309		
-10	-2.1	-.477	.224	.316	.110	-.485	0	-.049	.141	.042	.043	-.049	0	-.035	.137	.062	.027	-.035		
0	0	-.095	.192	.089	.087	-.095	2.0	.218	.157	-.094	.024	.223	2.0	.220	.152	-.091	.013	.225		
2.1	2.1	.274	.208	-.132	.058	.282	2.9	.353	.165	-.197	.008	.362	2.9	.359	.159	-.182	.003	.367		
3.0	3.0	.434	.225	-.246	.035	.445	5.0	.662	.206	-.397	0	.679	4.9	.696	.206	-.349	-.003	.671		
4.2	4.2	.653	.249	-.360	.038	.670	7.0	1.029	.276	-.577	-.013	1.048	6.9	.969	.276	-.522	-.011	.995		
5.0	5.0	.823	.266	-.483	.015	.843	8.0	1.245	.331	-.670	-.022	1.279	7.9	1.139	.335	-.587	-.016	1.175		
7.1	7.1	1.265	.345	-.754	-.035	1.298	10.1	1.631	.448	-.894	-.031	1.684	10.0	1.482	.442	-.781	-.027	1.536		
10.3	10.3	2.003	.562	-1.161	-.042	2.071	12.1	2.030	.600	-1.130	-.052	2.111	12.0	1.846	.580	-.998	-.032	1.927		
13.5	13.5	2.850	.870	-1.688	-.060	2.974														
10	-4.2	-.653	.249	.360	-.038	-.670	-2.0	-.218	.157	.094	-.024	-.223	-2.0	-.220	.152	.091	-.013	-.225		
-10	-2.1	-.274	.208	.132	.058	-.282	0	-.049	.141	.042	.043	-.049	0	-.035	.137	.062	.027	-.035		
0	0	-.095	.192	.089	.087	-.095	2.0	.218	.157	-.094	.024	.223	2.0	.220	.152	-.091	.013	.225		
2.1	2.1	.274	.224	-.316	.110	.285	2.9	.329	.186	-.322	-.084	.338	2.9	.346	.179	-.273	-.062	.340		
3.0	3.0	.693	.261	-.441	-.035	.706	5.0	.831	.247	-.509	-.106	.849	4.9	.771	.232	-.434	-.084	.768		
4.2	4.2	.866	.291	-.547	.132	.885	7.0	1.200	.328	-.713	-.127	1.231	6.9	1.101	.311	-.636	-.102	1.130		
5.1	5.1	1.090	.329	-.679	-.035	1.115	8.0	1.443	.396	-.830	-.128	1.485	7.9	1.247	.368	-.695	-.120	1.286		
7.1	7.1	1.521	.426	-.938	-.035	1.562	10.1	1.825	.488	-1.055	-.145	1.889	10.0	1.595	.486	-.893	-.134	1.654		
10.3	10.3	2.314	.667	-1.361	-.042	2.396	12.1	2.243	.688	-1.306	-.163	2.337	12.0	1.974	.644	-1.121	-.155	2.064		
13.5	13.5	3.157	1.005	-1.866	-.060	3.304														
-20	-4.2	-1.023	.361	.681	.270	-1.047	-2.1	-.434	.204	.288	.168	-.441	-2.0	-.403	.164	.276	.126	-.410		
-20	-2.1	-.628	.289	.439	.237	-.639	0	-.137	.166	.120	.118	-.137	0	-.122	.148	.120	.061	-.123		
0	0	-.247	.237	.205	.201	-.247	2.0	.157	.172	-.049	.062	.163	2.0	.140	.158	-.011	.036	.146		
2.1	2.1	.142	.245	-.035	.159	.150	2.9	.335	.187	-.184	.049	.345	2.9	.338	.169	-.188	.030	.346		
2.9	2.9	.321	.266	-.158	.140	.334	4.9	.661	.226	-.373	.027	.678	4.9	.636	.224	-.340	.019	.693		
5.0	5.0	.725	.312	-.404	.105	.750	7.0	1.026	.293	-.585	.015	1.054	6.9	.946	.288	-.510	.013	.974		
7.1	7.1	1.186	.364	-.681	.072	1.218	8.0	1.218	.319	-.703	.010	1.253	7.9	1.127	.338	-.636	.011	1.169		
10.2	10.2	1.982	.596	-1.224	.029	2.050	10.0	1.593	.456	-.915	.004	1.647	9.9	1.436	.427	-.812	.008	1.547		
12.3	12.3	2.537	.755	-1.573	.006	2.640	12.0	1.984	.615	-1.130	0	2.065	11.9	1.793	.565	-1.028	.005	1.946		
20	-2.1	-.142	.235	.035	-.159	-.150	-2.0	-.157	.172	.053	-.062	-.163	-2.0	-.140	.158	.011	-.038	-.146		
0	0	.247	.237	.205	.201	.247	0	.137	.166	-.120	.118	.137	0	.122	.148	-.120	.061	.123		
2.1	2.1	.628	.289	-.439	-.237	.639	2.1	.434	.204	-.288	-.168	.441	2.0	.403	.164	.276	.126	.410		
3.0	3.0	.812	.331	-.545	-.270	.829	2.9	.584	.236	-.377	-.197	.595	2.9	.566	.211	-.348	-.154	.576		
4.2	4.2	1.023	.361	-.681	-.072	1.047	5.0	.921	.299	-.577	-.127	.943	4.9	.900	.285	-.536	-.197	.921		
5.1	5.1	1.225	.412	-.801	-.035	1.256	7.0	1.300	.394	-.805	-.257	1.339	6.9	1.247	.386	-.743	-.235	1.285		
7.2	7.2	1.645	.517	-1.001	-.327	1.696	8.0	1.522	.459	-.873	-.296	1.571	7.9	1.378	.442	-.757	-.274	1.426		
10.4	10.4	2.416	.765	-1.470	-.369	2.514	10.1	1.937	.602	-1.113	-.330	2.012	10.0	1.747	.579	-.979	-.323	1.821		
13.5	13.5	3.197	1.120	-1.593	-.033	3.371	12.1	2.369	.785	-1.373	-.365	2.481	12.0	2.131	.752	-1.199	-.366	2.241		
-30	-4.3	-1.186	.483	.800	.421	-1.219	-2.1	-.567	.285	.389	.306	-.577	-2.0	-.507	.254	.339	.255	-.516		
-20	-2.2	-.773	.393	.545	.378	-.789	0	-.233	.217	.188	.249	-.233	0	-.192	.192	.159	.180	-.192		
-10	-0.1	-.367	.315	.293	.330	-.367	2.0	.108	.186	-.025	.135	.115	2.0	.128	.170	-.031	.091	.134		
0	0	.049	.287	.032	.242	.059	2.9	.286	.194	-.157	.071	.296	2.9	.307	.188	-.168	.046	.317		
2.9	2.9	.221	.292	-.092	.177	.235	4.9	.602	.222	-.340	.038	.619	4.9	.601	.223	-.331	.024	.618		
5.0	5.0	.639	.314	-.356	.130	.664	7.0	.972	.285	-.566	.021	1.000	6.9	.915	.281	-.506	.016	.942		
7.1	7.1	1.112	.373	-.629	.089	1.149	8.0	1.176	.348	-.661	.015	1.213	7.9	1.091	.339	-.606	.008	1.128		
10.2	10.2	1.945	.604	-1.182	.047	2.110	10.0	1.561	.457	-.887	.011	1.616	9.9	1.429	.442	-.808	.008	1.484		
13.4	13.4	2.976	.818	-1.887	.033	2.660	12.0	1.953	.605	-1.129	.010	2.037	11.9	1.784	.584	-1.018	.005	1.866		
30	-2.0	-.049	.287	-.032	-.242	-.059	-2.0	-.108	.186	.025	-.135	-.115	-2.0	-.128	.170	.031	-.091	-.134		
0.1	0.1	.367	.315	-.293	-.330	.367	0	.233	.217	-.188	-.249	.233	0	.192	.192	.159	-.180	.192		
2.2	2.2	.773	.393	.545	.378	.789	2.1	.567	.285	-.389	-.306	.577	2.0	.507	.254	-.339	-.255	.516		
4.3	4.3	1.186	.483	-.800	-.421	1.219	3.0	.936	.355	-.671	-.343	.996	2.9	.907	.313	-.422	-.293	.685		
7.2	7.2	1.927	.670	-1.275	-.460	1.995	5.0	1.097	.444	-.733	-.391	1.131	4.9	1.025	.412	-.638	-.368	1.056		
10.3	10.3	2.729	.935	-1.738	-.510	2.774	7.0	1.484	.565	-.966	-.433	1.542	7.0	1.407	.539	-.872	-.430	1.462		
							8.0	1.753	.645	-1.119	-.464	1.819	7.9	1.615	.562	-.101	-.466	1.677		
							10.1	2.171	.813	-1.387	-.498	2.274	10.0	2.006	.730	-.1257	-.504	2.102		
							12.1	2.693												

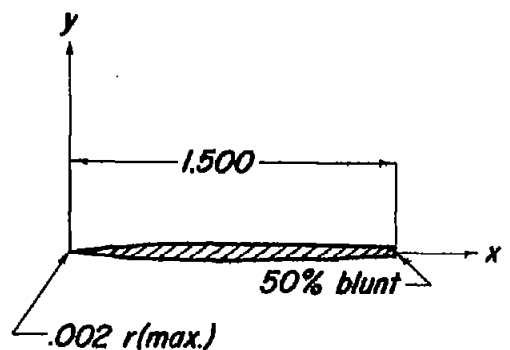
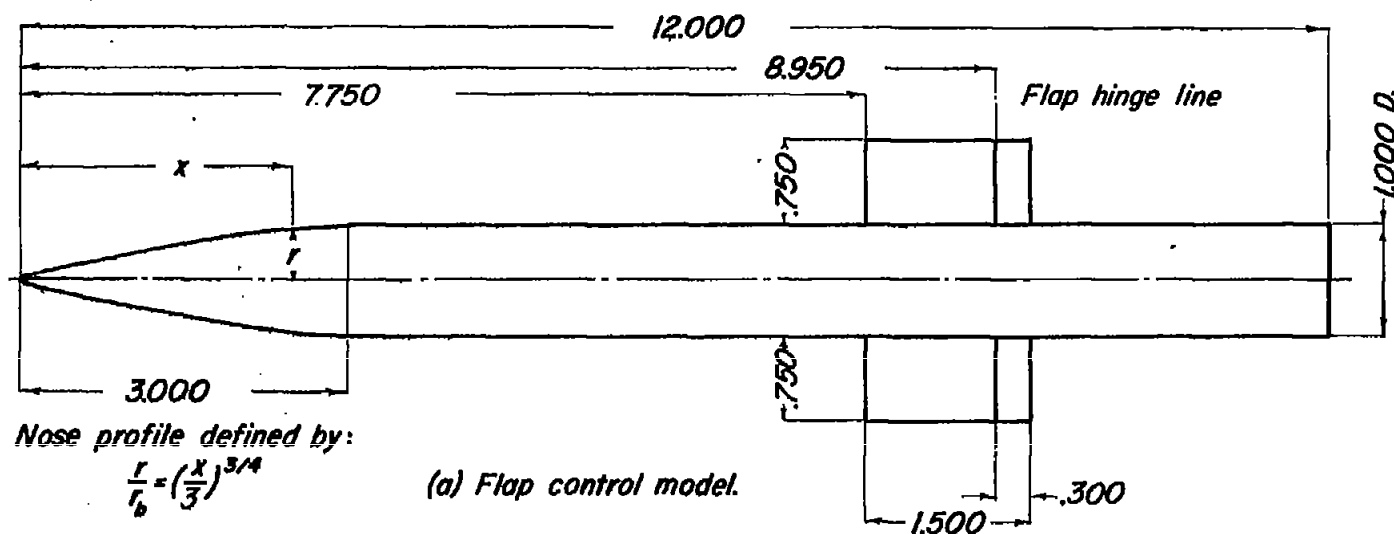
TABLE I.- AERODYNAMIC CHARACTERISTICS OF CONTROL-WING-BODY COMBINATIONS
(b) Trailing-edge spoiler control

h, percent	M = 3.00					M = 4.23					M = 5.05				
	α	C_L	C_D	C_N	C_m	α	C_L	C_D	C_N	C_m	α	C_L	C_D	C_N	C_m
-4	-4.2	-0.779	0.288	-0.798	0.486	-2.0	-0.344	0.166	-0.350	0.208	-2.0	-0.283	0.163	-0.288	0.171
	-2.1	-.394	.236	-.402	.252	0	-.044	.151	-.044	.032	0	-.018	.139	-.018	.032
	0	-.048	.202	-.048	.046	2.0	.227	.178	.232	-.123	2.0	.232	.153	.238	-.105
	2.1	.288	.230	.296	-.153	2.9	.404	.184	.413	-.239	2.9	.425	.176	.434	-.246
	3.0	.464	.256	.476	-.269	5.0	.727	.230	.744	-.424	4.9	.760	.227	.776	-.442
	5.0	.858	.311	.882	-.515	7.0	1.096	.304	1.125	-.646	6.9	1.027	.301	1.056	-.577
	7.1	1.302	.402	1.342	-.786	8.0	1.275	.348	1.312	-.735	7.9	1.152	.335	1.187	-.650
	8.1	1.565	.458	1.614	-.958	10.0	1.660	.465	1.715	-.957	9.9	1.498	.447	1.553	-.845
	10.2	2.121	.609	2.195	-1.300	12.1	2.071	.622	2.155	-1.207	12.0	1.870	.588	1.951	-1.071
	12.3	2.674	.831	2.790	-1.638										
4	-2.1	-.288	.230	-.296	.153	-2.0	-.227	.166	-.232	.123	-2.0	-.214	.149	-.219	.110
	0	.048	.202	.048	.046	0	.044	.151	.044	.032	0	.048	.134	.048	-.036
	2.1	.394	.236	.402	-.252	2.0	.344	.178	.350	-.208	2.0	.334	.158	.339	-.204
	4.2	.778	.288	.798	-.486	2.9	.454	.203	.464	-.267	2.9	.442	.198	.452	-.262
	8.2	1.868	.528	1.924	-1.193	5.0	.776	.257	.795	-.452	4.9	.747	.246	.765	-.433
	10.3	2.416	.705	2.503	-1.545	7.0	1.149	.339	1.182	-.671	6.9	1.072	.325	1.103	-.616
						8.0	1.508	.397	1.549	-.927	7.9	1.304	.380	1.345	-.765
-8	-4.2	-.980	.418	-1.009	.640	-2.1	-.414	.242	-.423	.278	-2.0	-.433	.229	-.441	.288
	-2.1	-.589	.339	-.601	.402	0	-.124	.192	-.124	.105	0	-.124	.190	-.124	.108
	0	-.217	.279	-.207	.174	2.0	.161	.180	.168	-.055	2.0	.148	.190	.155	-.051
	2.1	.155	.274	.165	-.055	2.9	.376	.190	.385	-.220	2.9	.378	.194	.387	-.208
	2.9	.392	.279	.406	-.221	5.0	.698	.230	.715	-.410	4.9	.687	.228	.704	-.377
	5.0	.789	.334	.815	-.466	7.0	1.079	.301	1.107	-.635	6.9	1.009	.296	1.037	-.559
	7.1	1.260	.408	1.300	-.763	8.0	1.263	.345	1.299	-.720	7.9	1.143	.338	1.178	-.635
	10.2	2.088	.604	2.162	-1.275	10.0	1.643	.463	1.698	-.938	9.9	1.493	.438	1.546	-.838
	12.3	2.712	.829	2.771	-1.634	12.1	2.056	.621	2.140	-1.191	12.0	1.867	.585	1.948	-1.069
8	-2.1	-.155	.274	-.165	.055	-2.0	-.150	.191	-.157	.060	-2.0	-.148	.190	-.155	.051
	0	.217	.279	.217	-.174	0	.136	.196	.136	-.107	0	.124	.190	.124	-.108
	2.1	.589	.339	.601	-.402	2.0	.432	.239	.440	-.284	2.0	.433	.229	.441	-.288
	4.2	.980	.418	1.009	-.640	2.9	.550	.261	.562	-.350	2.9	.503	.239	.514	-.302
	7.1	1.737	.584	1.796	-1.125	5.0	.884	.332	.909	-.552	4.9	.829	.317	.854	-.487
	10.3	2.544	.860	2.657	-1.642	7.0	1.260	.430	1.303	-.778	6.9	1.174	.409	1.214	-.691
						8.0	1.606	.425	1.650	-.988	7.9	1.433	.484	1.485	-.863
						10.0	2.033	.623	2.111	-1.256	9.9	1.835	.631	1.916	-1.116
						12.1	2.466	.866	2.593	-1.538	12.0	2.190	.830	2.314	-1.325

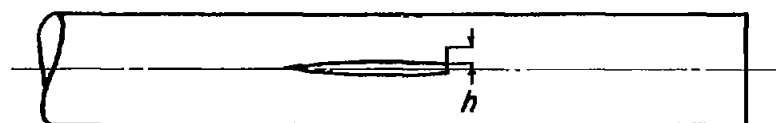
A rectangular stamp with the word "CONFIDENTIAL" in a bold, sans-serif font. The stamp is slightly tilted and has a dark, textured background.

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A rectangular stamp with the word "CONFIDENTIAL" in a bold, sans-serif font. The stamp is slightly tilted and has a dark, textured background.



4-percent-thick biconvex airfoil profile
defined by: $\frac{y}{c} = -8.466 + \sqrt{71.683 + 1.171 \frac{x}{c} - \left(\frac{x}{c}\right)^2}$



Note: All dimensions in inches.

Figure 1.- Principal dimensions of test models.

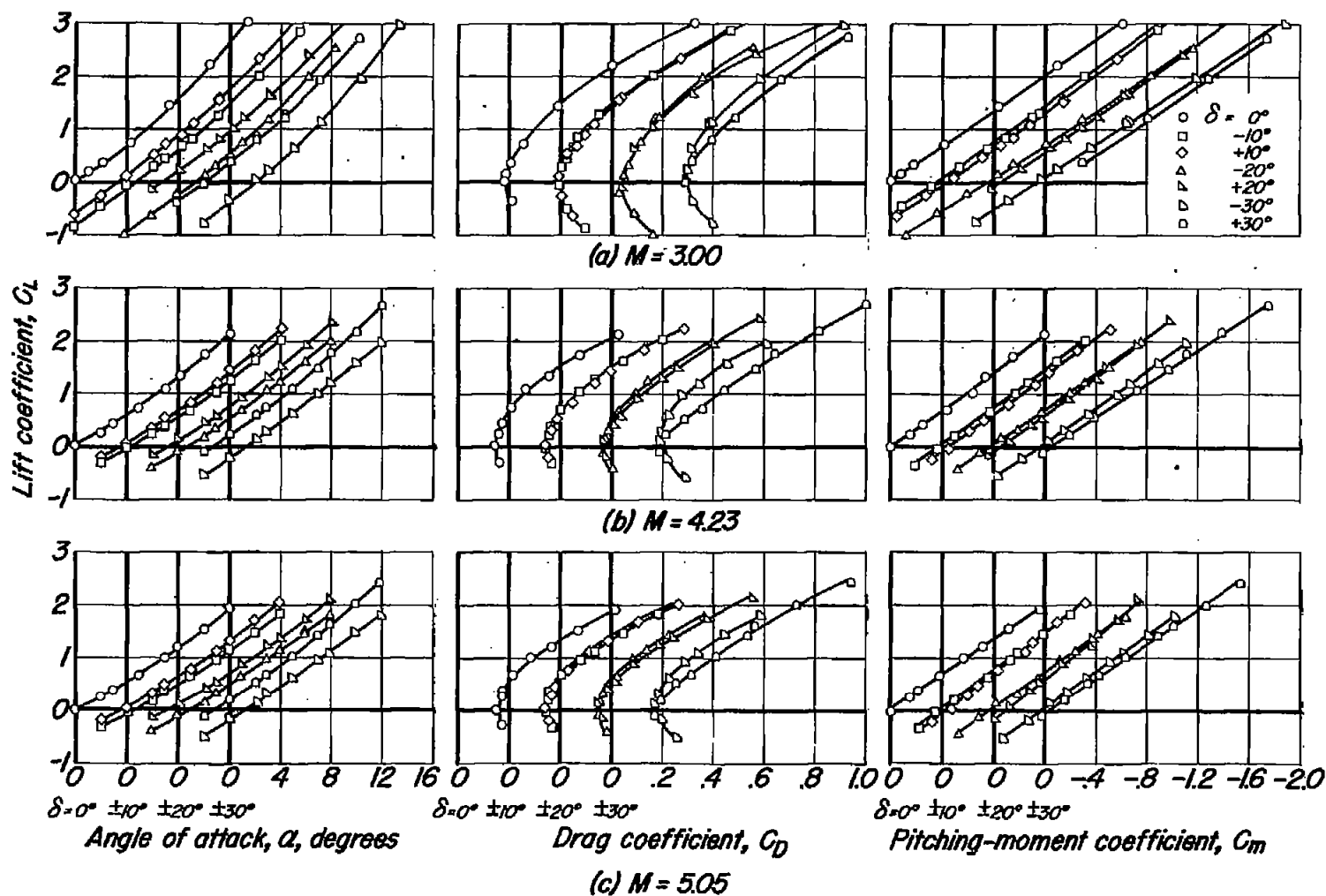


Figure 2.- Aerodynamic characteristics of the wing-body combination with a 20-percent-chord trailing-edge flap.

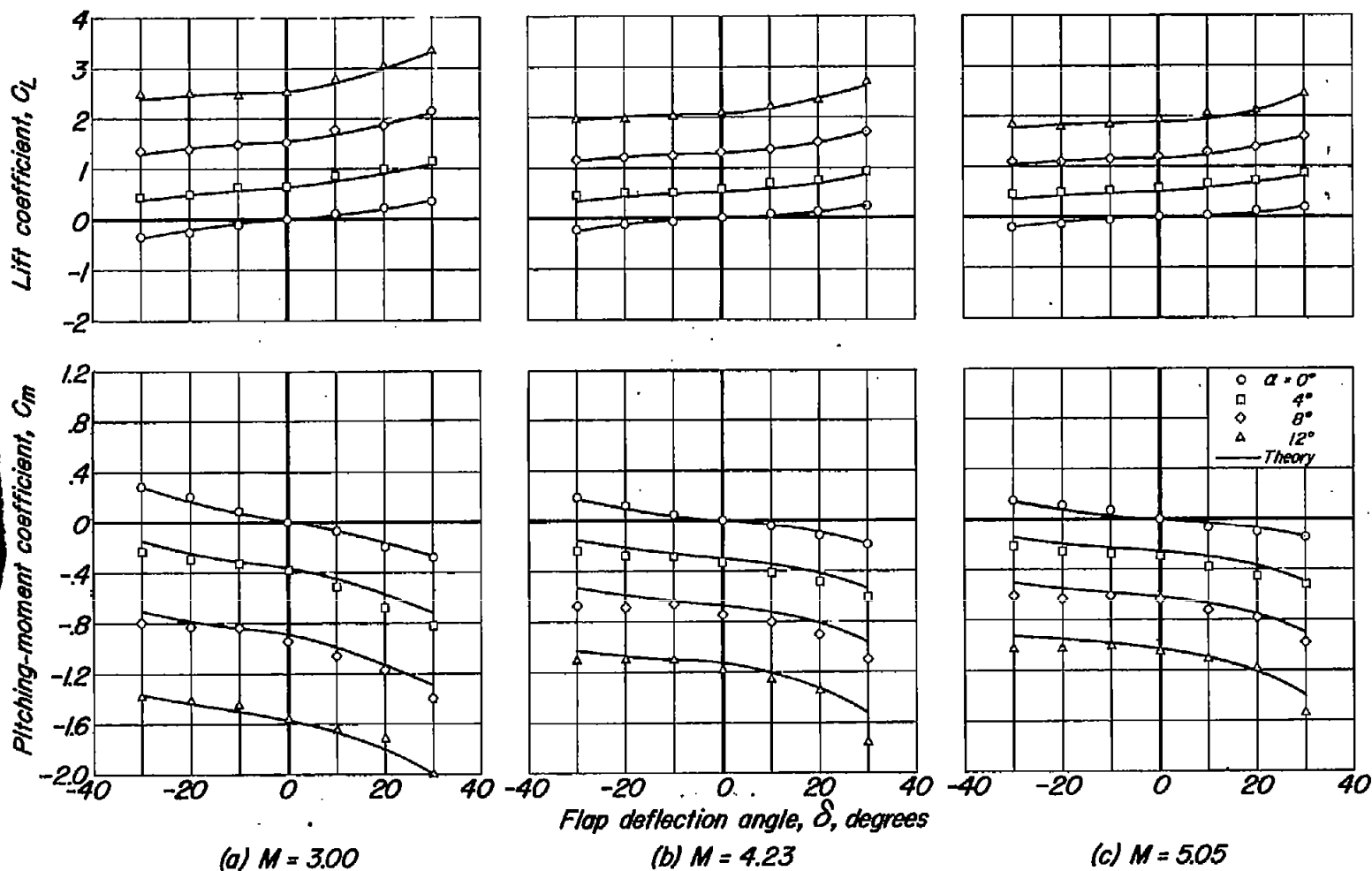


Figure 3.- Variation of lift coefficient and pitching-moment coefficient with flap deflection angle.

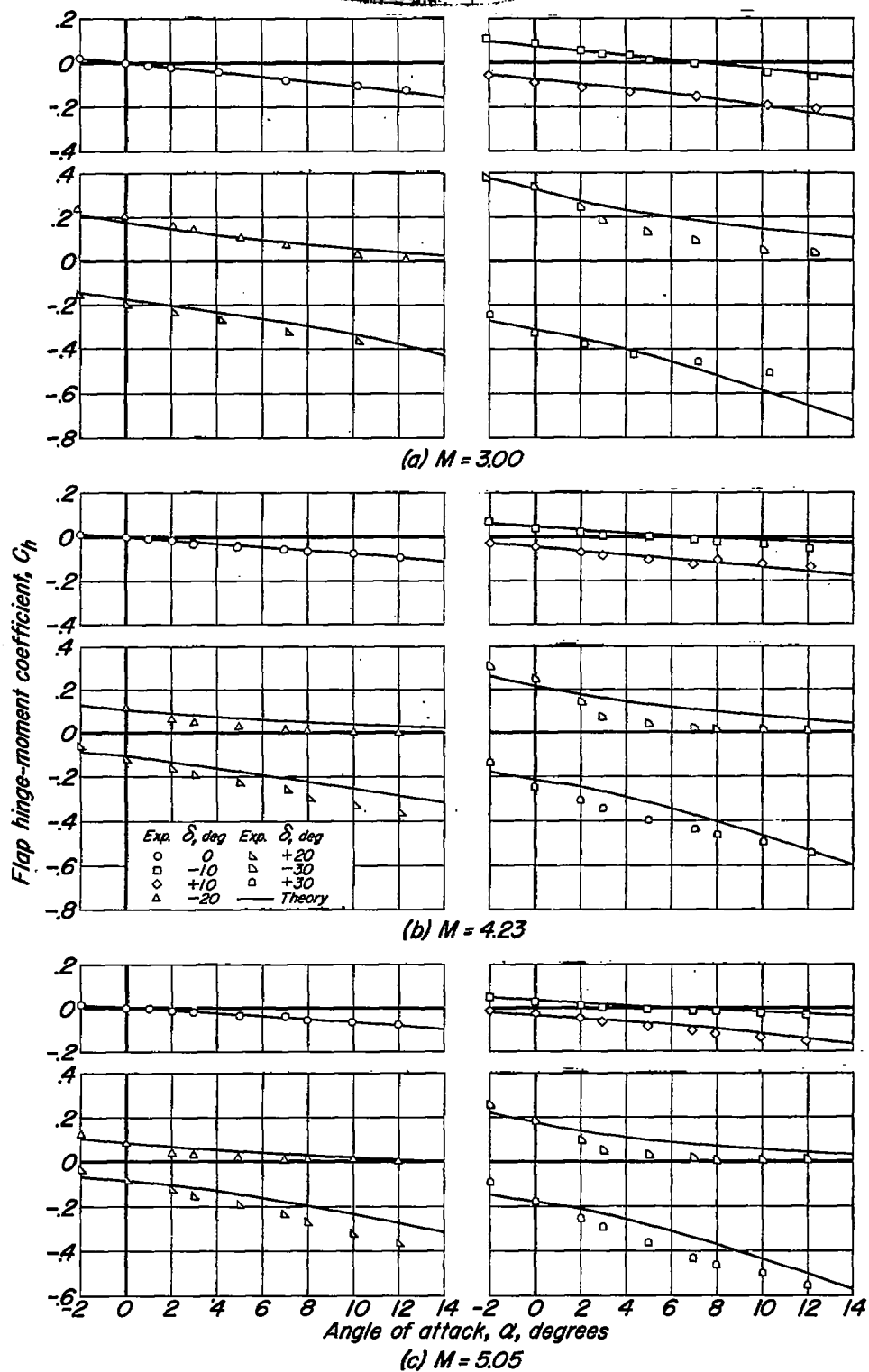


Figure 4.— Variation of flap hinge-moment coefficient with angle of attack.

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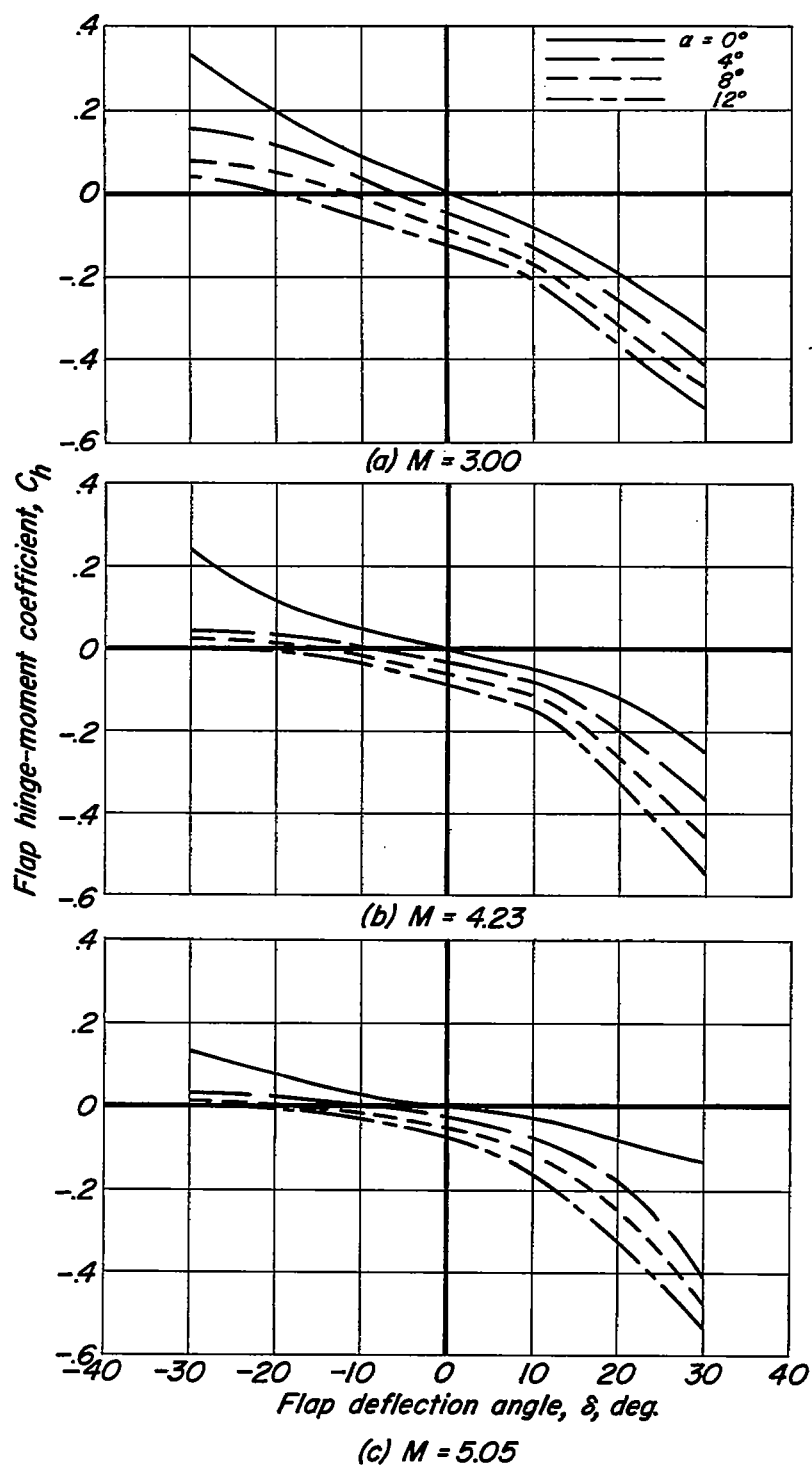


Figure 5.- Variation of flap hinge-moment coefficient with flap deflection angle.

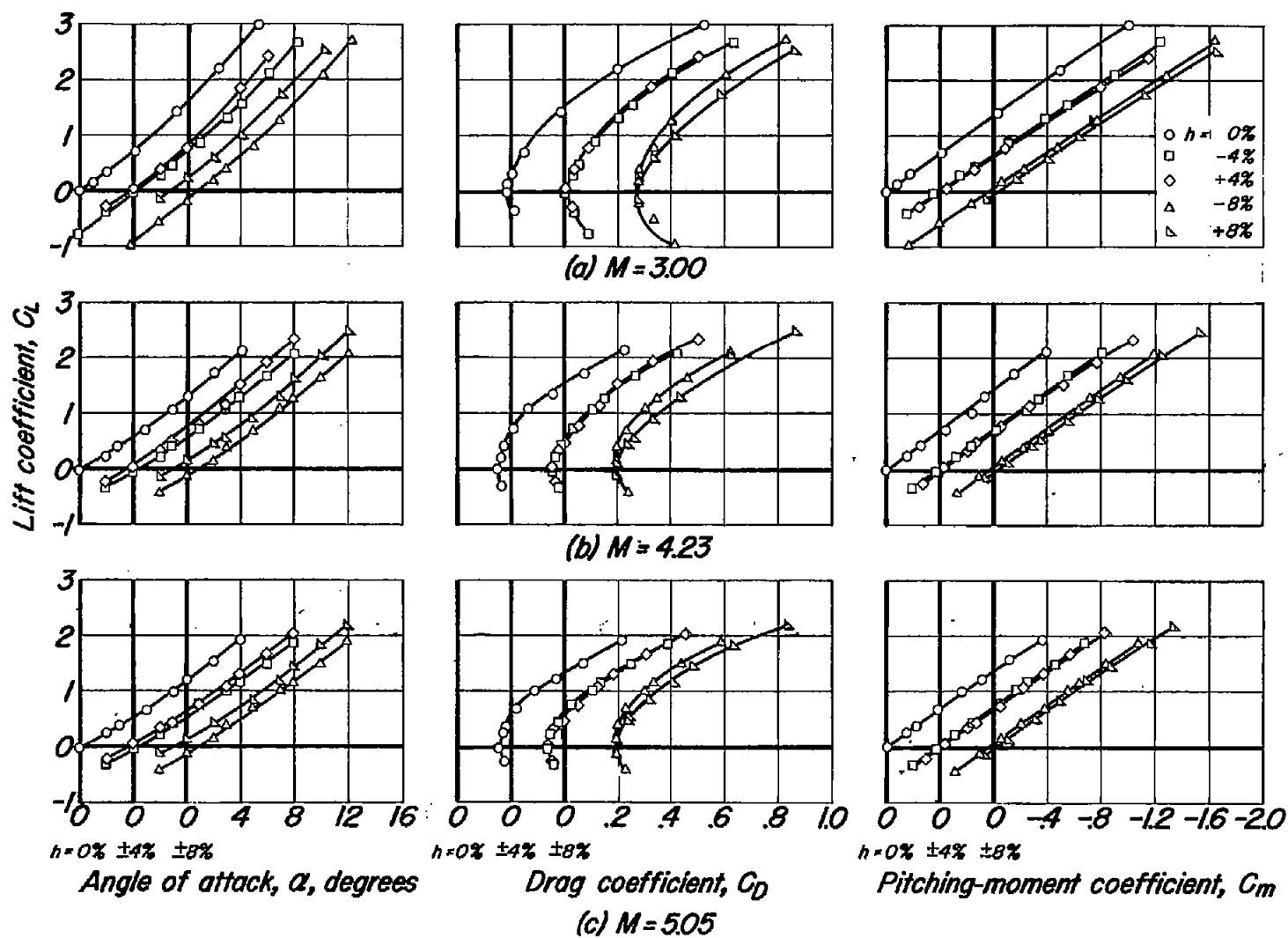


Figure 6.- Aerodynamic characteristics of the wing-body combination with a full-span trailing-edge spoiler.

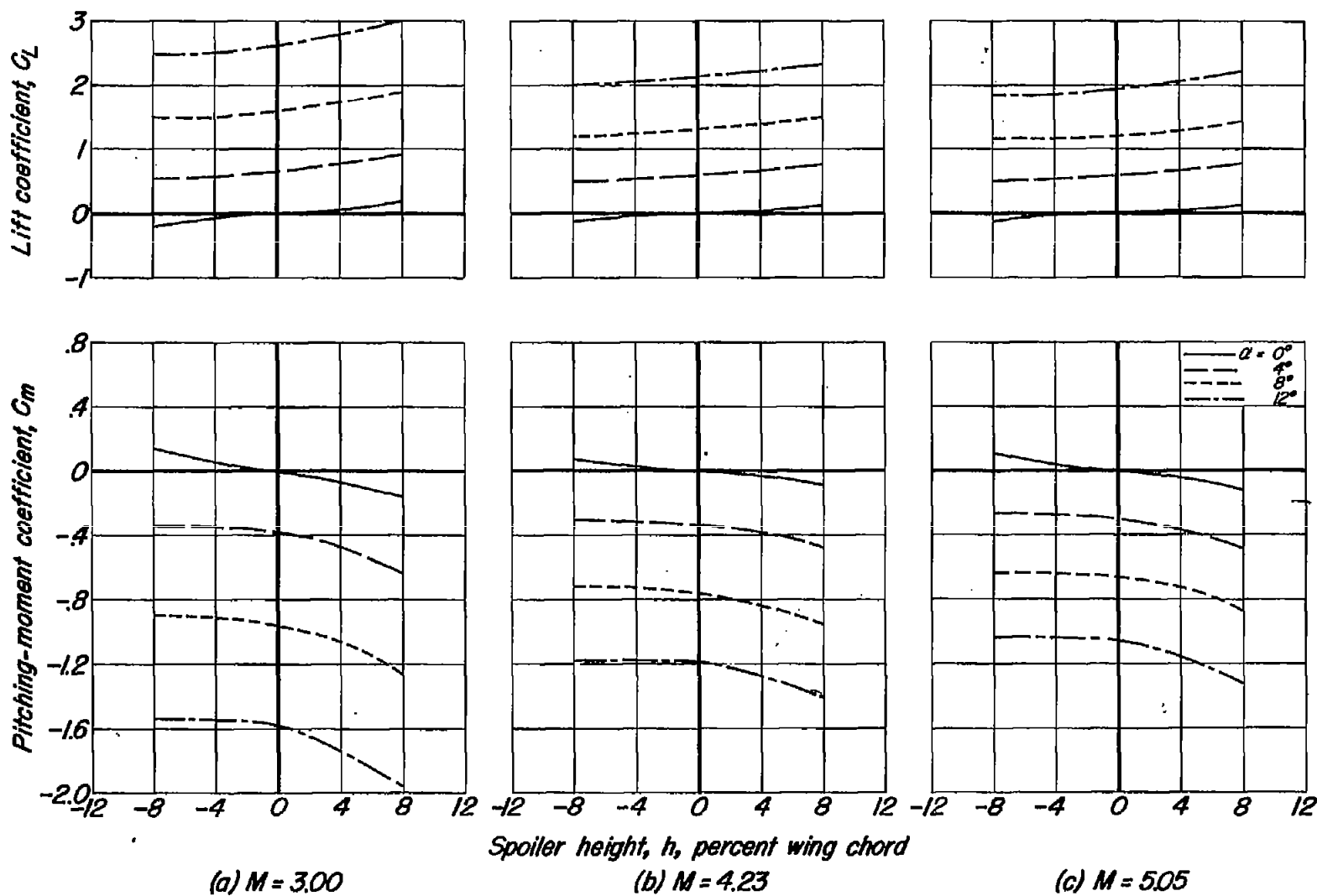


Figure 7.- Variation of lift coefficient and pitching-moment coefficient with spoiler height.

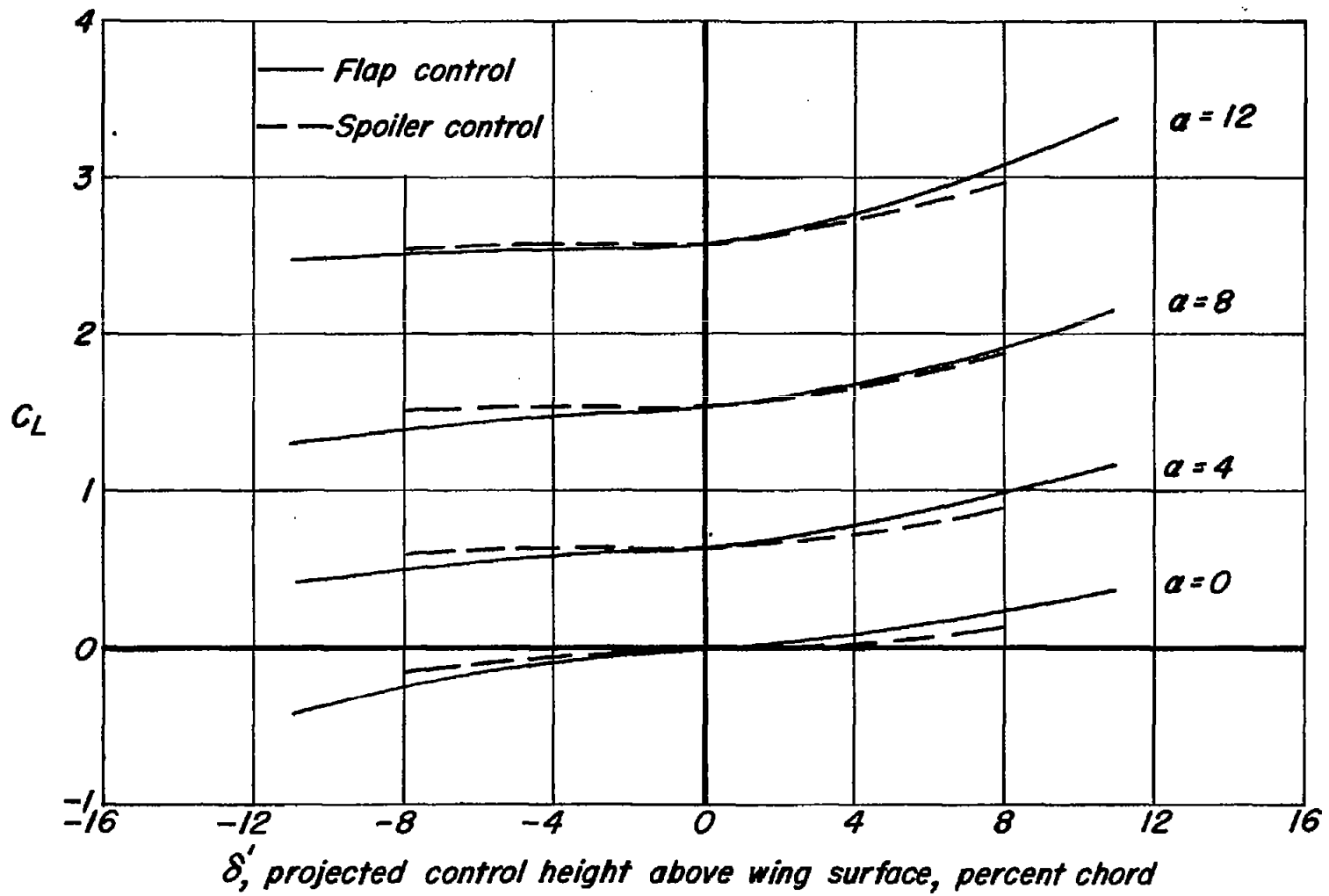


Figure 8.— Variation of lift coefficient with projected control height at $M = 3.00$.

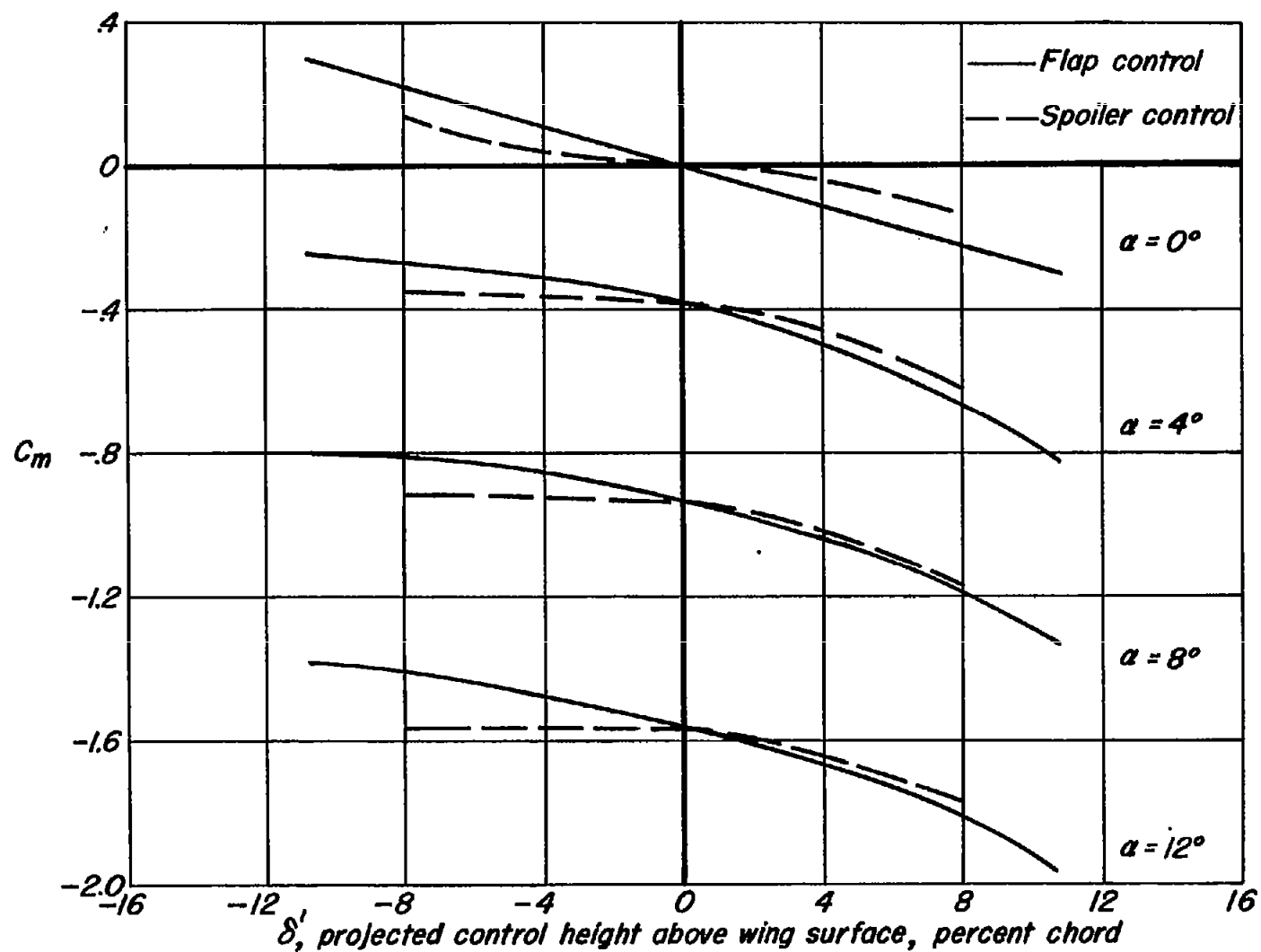


Figure 9.— Variation of pitching-moment coefficient with projected control height at $M = 3.00$.

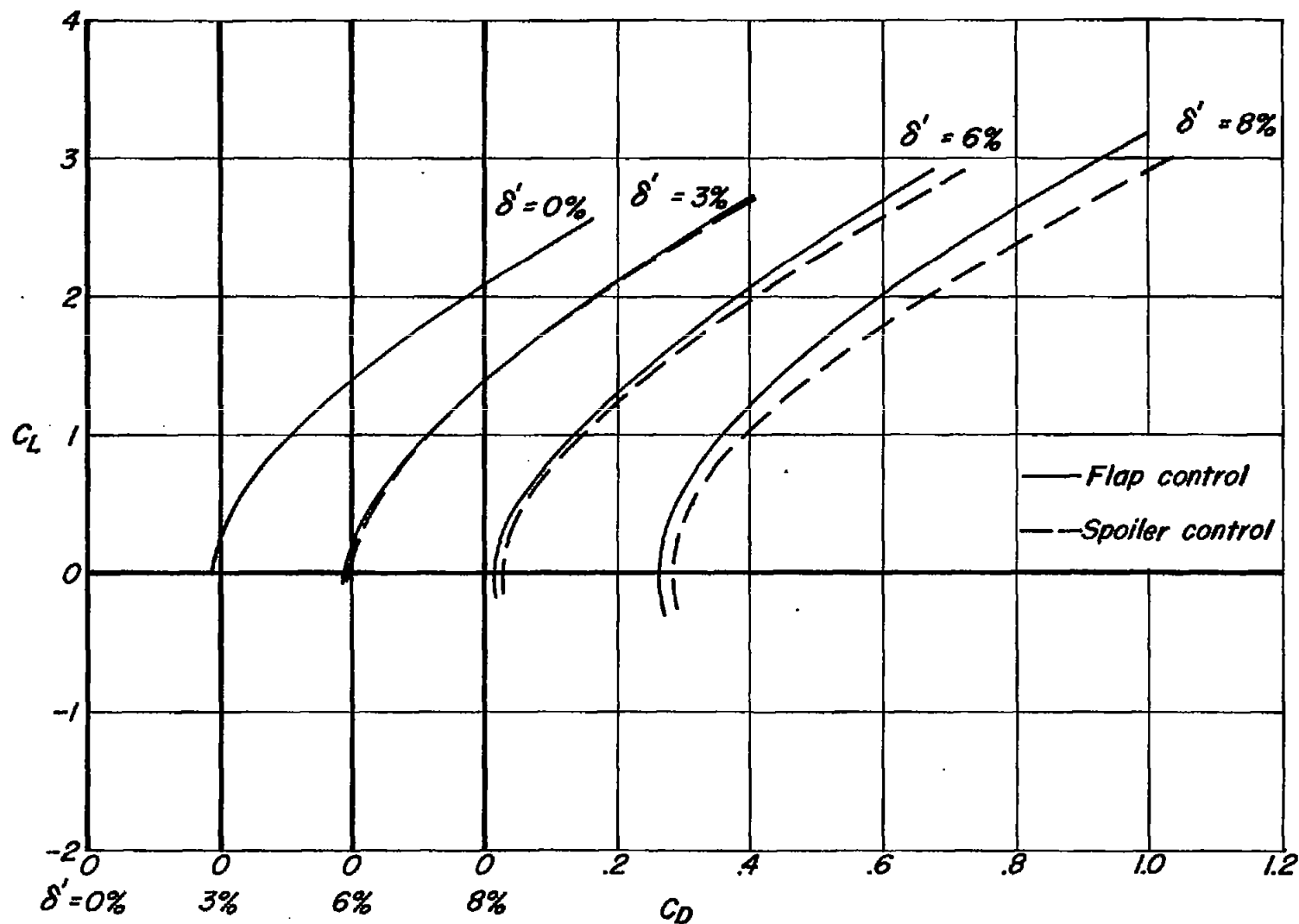


Figure 10.- Relative efficiency of the two control-wing-body combinations at $M = 3.00$.